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Evidence of superconducting and magnetic fluctuations both above and below T_c in $BaFe_{2-x}Co_xAs_2$ single crystals

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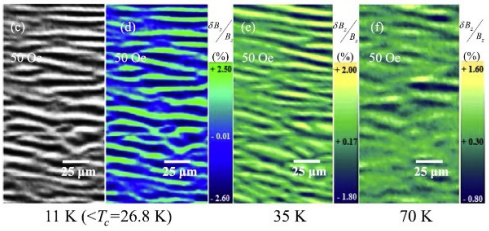
The doping phase diagram in Pnictide superconductors has magneto-structural transformation boundaries interrupted by a superconducting dome. Unraveling the intricate relationship between superconductivity, magnetism and structural transformation in Pnictides is a topic of current interest. With doping, long range magnetic order gets suppressed and superconductivity emerges in these compounds, with the bulk superconducting transition temperature (T_c) becoming maximum at an optimal doping concentration (x). MuSR studies on $Ba(Fe_{1-x}Co_x)_2As_2$ have shown that while Co doping results in loss of long range magnetic order, short range order may still be present in the system. Studies on underdopedPnicitdes show the coexistence of superconductivityalong with magnetic fluctuations below T_c. Theories also suggest that magnetism plays an important role in mediating strong superconducting pairing correlations in Pnictides. It seems likely that magnetism of some form is important for sustaining superconducting correlations in these doped compounds. Using high sensitivity magneto-optical imaging technique [i]and SQUID magnetization measurements, we probe the behavior of local and bulk magnetization response measured in, under, optimally and over, doped, superconducting $BaFe_{2-x}Co_xAs_2$ single crystals. At low applied H for $T < T_c$, local magnetization measurements we show the presence of weak positive magnetization response in the optimally doped crystal. The local positive magnetic response transforms into a diamagnetic response with increasing H. Just above T_c, in all the crystals the bulk magnetization response becomes positive and exhibits a maxima along with a long tail extending upto high T. Through analysis of this maxima feature in bulk magnetization and electrical conductivity measurements in the normal state along with sensitive imaging of local magnetic field distribution, we show the presence of superconducting fluctuations above T_c[i]. At $T > T_c$the local regions with superconducting response coexist with regions having magnetic fluctuations. We observe that the crystal with optimum doping concentration exhibits the strongest effect of magnetic fluctuations and it also possesses the highest superconducting volume fraction above T_c. Using the data gathered for each doping concentration, we construct the H - T diagrams in which different fluctuation regimes have been identified.We believe our results suggest the importance of magnetic fluctuation in mediating superconducting order in the $BaFe_{2-x}Co_xAs_2$system. Another interesting aspect of the presence of magnetic fluctuations along with the superconductivity is that it leads to novel competing effects deep in the superconducting state and affects the vortex distribution in this system [ii].



The adjoining figures shows imaging the presence of regions with diamagnetic fluctuations (bluishregions) coexisting along with magnetic fluctuations (greenish shade regions) both above and below Tc (= 26.8 K) in optimally doped BaFe2-xCoxAs2 single crystal. (Ref. [1]). We show well above Tc regions with superconducting fluctuations coexist along with regions with magnetic order.

[i]Biplab Bag, K. Vinod, A. Bharathiand **S. S. Banerjee**. New J. Phys. 18 (2016) 063025
[ii]Biplab Bag, K. Vinod, A. Bharathiand **S. S. Banerjee**. (submitted).